

## REMARKS

Reconsideration and allowance of this application, as amended, is respectfully requested. Claims 1-23 are pending in this application. Claims 10-15 and 21-23 have been amended. The specific changes to the claims are shown above, wherein the insertions are underlined and the ~~deletions are stricken through~~.

Applicants submit that this application, as amended, is in condition for allowance and such action is earnestly requested. Each of the Office Action's reasons for rejection is addressed below.

### A. Section 112

Claim 10 is rejected under 35 U.S.C. § 112, second paragraph, as being unclear as to whether the claim is directed to a processing tool alone or the combination of a processing tool and a FOUP cassette. Claim 10 has been amended to focus on the combination. Dependent Claims 11-13 have been amended for consistency with the preamble of Claim 10. Accordingly, Applicants respectfully request that this rejection be withdrawn.

The Office Action correctly notes that Claim 14 is directed to a processing tool alone, without the substrate cassette. Accordingly, Claim 14 is amended to delete "a cassette rack internal to the docked cassette." Dependent Claims 15 and 21-23 are amended to focus on the combination.

### B. Section 103(a) – Hofmeister in view of Tanaka and Ozawa

Claims 1-6 and 10-23 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Hofmeister (U.S. Patent No. 6,481,956) in view of Tanaka (U.S. Patent No. 6,395,094), and further in view of Ozawa (U.S. Patent No. 5,810,538). Applicants respectfully disagree with and traverse this rejection.

#### 1. Disclosure of Hofmeister, Tanaka, and Ozawa

Hofmeister discloses, in Figure 2, an apparatus including cassette load ports 26 for receiving substrate cassettes or capsils 34. The apparatus further includes a cassette stocker 24,

substrate cassette pod door removers 28, a loading section 13, a substrate transport robot 32 within the loading section 13, and load locks 16 connected to the loading section 32. The loading section 13 contains four buffer cassettes B1-B4. Hofmeister teaches using the buffer cassettes B1-B4 as temporary substrate storage locations within the loading section 13, and states that "[t]he buffers may be eliminated if there is no pre or post align or if repeated capsil access is acceptable." Col. 3, lines 28-39.

Tanaka discloses, in Figure 1a, a process system including wafer cassette housing chambers 30A and 30B, a transfer chamber 28, process chambers 26A-D, and buffer parts 44 and 46. A system 100 supplies the transfer chamber 28 and cassette housing chambers 30A and 30B with an inert gas, such as N<sub>2</sub>, and these chambers are also provided with a vacuum exhaust system 102. Col. 7, lines 51-54. Referring to Figures 2-5, each buffer part 44, 46 includes a single-wafer preheating unit 48 and a single-wafer cooling unit 50. Each buffer part 44, 46 can be airtightly separated from the transfer chamber 28 during wafer preheating or cooling. The cooling unit 50 includes a cooling gas system 94 for selectively introducing a cooling gas, such as a cooled N<sub>2</sub> gas, and an exhaust system 96 connected to a vacuum pump or the like for discharge of the cooling gas. Col. 7, lines 36-44.

Ozawa discloses, in Figure 1, semiconductor manufacturing equipment comprising an enclosure 37 having a front shutter 38. A multi-shelf cassette stocker 24 is positioned for transferring, via a vertically movable cassette transfer unit 40, cassettes 26 to/from a cassette stage 39, which is adjacent the front shutter 38. The tool also comprises a reaction chamber 15, a load-lock chamber 17, and a boat elevator 30 for loading and unloading a boat 18 to and from the reaction chamber 15. A carrying elevator 22 is face-to-face with the boat elevator 30. The carrying elevator 22 is provided with a wafer carrier 23 (for transferring as many wafers as desired from the boat elevator 18 to the cassette stocker 24), and a wafer holder (not shown) is designed such that its pitch can be adjusted to match either the pitch of the wafers held within the wafer cassettes 26 or the pitch of the wafers held within the boat 18. Ozawa, col. 4, lines 45-50.

## **2. The Law of Obviousness**

In an obviousness rejection based on a combination of references, the claimed invention "is not proved obvious merely by demonstrating that each of its elements was, independently,

known in the prior art.” *KSR International Co. v. Teleflex Inc., et al.*, 127 S.Ct. 1727, 1741 (2007). “[I]t can be important to identify a reason that would have prompted a person of ordinary skill in the relevant field to combine the elements in the way the claimed new invention does.” *Id.* It will often “be necessary ... to look to interrelated teachings of multiple patents; the effects of demands known to the design community or present in the marketplace; and the background knowledge possessed by a person having ordinary skill in the art, all in order to determine whether there was an apparent reason to combine the known elements in the fashion claimed by the patent at issue. To facilitate review, this analysis should be made explicit.” *Id.* at 1740-41.

Also, to establish a *prima facie* case of obviousness, there must be a reasonable expectation of success for a proposed modification of a prior art reference. M.P.E.P. § 706.02(j); *In re Vaeck*, 947 F.2d 488, 493 (Fed. Cir. 1991).

### 3. Logic of the Rejection

In its rejection, the Office Action points to Hofmeister’s loading section 13 and buffer cassettes B1-B4 as the claimed “substrate handling chamber” and “buffer station,” respectively. With regard to the claimed limitation that “the buffer station [is] purged with an inert internal environment separate from the first substrate handling chamber,” the Office Action points to Tanaka’s cooling gas system 94 of the buffer stations 44 and 46. In particular, the Office Action refers to Tanaka’s teaching of airtightly separating the buffer station 44, 46 from the transfer chamber 28 during wafer preheating or cooling “to prevent a gas, which has been released or exhausted from the surface of the object during preheating, and a cooling gas, which has been used for cooling, from being leaked into the transfer chamber.” Tanaka, col. 3, lines 43-47. The Office Action indicates that it would have been obvious to modify one of Hofmeister’s buffer cassettes B1-B4 to comprise a buffer station directly adjacent the loading section 13, and to purge the buffer station with an inert internal environment separate from the loading section 13, “as per the teachings of Tanaka, to contain leakage into a transfer chamber.” Office Action, page 4. Applicants’ respectfully disagree with the Office Action’s conclusion that it would have been obvious to combine Hofmeister and Tanaka in the manner asserted.

4. Nonobviousness Argument

Regarding the purported reason to combine Hofmeister and Tanaka, the Office Action is somewhat vague. On its face, it states that the reason to combine is "to contain leakage into a transfer chamber." However, since Hofmeister does not express any desire to cool or separately purge the buffer cassettes B1-B4, Hofmeister does not have the problem of leakage into a transfer chamber. Thus, the Office Action on its face indicates that the reason for the combination is to solve a problem that does not exist within either of the two references, which is clearly nonsensical.

On the other hand, the Office Action's position may be that it would have been obvious to fluidly separate at least one of Hofmeister's buffer cassettes B1-B4 from the loading section 13 and to provide the buffer cassette with Tanaka's cooling gas system 94. In other words, the Office Action may be saying that Tanaka made it obvious to convert one of Hofmeister's buffer cassettes B1-B4 into a wafer cooling station. Applicants disagree because there would not have been a reasonable expectation of success for this proposed modification of Hofmeister. Tanaka's cooling unit 50 is designed for cooling a *single wafer*. The cooling unit 50 includes three supporting pins 90 for supporting a hot wafer (e.g., 600°C; see Tanaka at col. 9, lines 7-8) inserted into the cooling unit 50. As generally known in the art, such pins are typically formed of a material capable of withstanding very high temperatures, so that they can be used during the cooling of hot wafers. Tanaka's supporting pins 90 are not capable of supporting multiple wafers.

In contrast, each of Hofmeister's buffer cassettes B1-B4 holds multiple substrates. Hofmeister does not describe the material properties of the buffer cassettes B1-B4. Nor does Hofmeister disclose cooling wafers within the buffer cassettes B1-B4. Therefore, skilled artisans would have interpreted Hofmeister's buffer cassettes B1-B4 as conventional cassette racks designed to hold substrates at ambient temperatures. Conventional cassette racks are not designed to receive hot wafers or to hold hot wafers during substrate cooling. For example, U.S. Patent No. 6,073,366 to Aswad<sup>1</sup> states:

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<sup>1</sup> A copy of U.S. Patent No. 6,073,366 to Aswad is submitted herewith for the Examiner's convenience.

“Because of the high temperature CVD processing, transport from the process chamber directly to a wafer cassette is not possible due to the temperature of the wafer exceeding the material properties of most commonly used cassette materials. Because of this, the transfer of the wafer to a cassette must be postponed until the wafer temperature falls below the thermal properties of the cassette material. While cassettes are available that can handle wafers as hot as 170°C., they are relatively expensive. A commonly available less expensive one made of Delrin® can only handle temperatures well below 100°C. Other commonly available units can only handle about 60°C.”

Aswad, col. 1, lines 25-38. Thus, it was understood that cassette racks cannot be used to cool substrates that are hotter than 170°C. Therefore, skilled artisans would not have had a reasonable expectation of success for the Office Action’s proposed modification of Hofmeister’s buffer cassettes B1-B4 to act as substrate cooling stations. Applicants respectfully assert that had the skilled artisan desired to provide a substrate cooling station in Hofmeister, he or she would have opted to provide a *single-substrate* cooling station (such as Tanaka’s cooling unit 50) *in addition to* the buffer cassettes B1-B4, as opposed to converting one of the buffer cassettes B1-B4 into a cooling station.

Thus, for the above reasons, Applicants assert that there was no apparent reason to combine Hofmeister and Tanaka in the manner claimed. The Office Action cites Ozawa for assertedly making it obvious to store substrates in a buffer station at a reduced pitch relative to a FOUNDED. First, this aspect of Ozawa is irrelevant to independent Claims 1 and 14, neither of which recites a reduced pitch buffer station. Second, with respect to independent Claim 10, Ozawa does not actually make it obvious to store substrates in a buffer station at a reduced pitch. Ozawa merely discloses a wafer holder designed such that its pitch can be adjusted to match either the pitch of a wafer cassette or the pitch of a wafer boat. Ozawa, col. 4, lines 45-50. Thus, while Ozawa might have suggested modifying Hofmeister to include an adjustable-pitch substrate holder, it would not have suggested modifying the pitch of Hofmeister’s buffer cassettes B1-B4.

Thus, since there was no apparent reason to combine Hofmeister, Tanaka, and Ozawa in the manner claimed, Applicants respectfully request that the rejection of independent Claims 1, 10, and 14 be withdrawn. Dependent Claims 2-9, 11-13, and 15-23 recite additional features of advantage and utility. Furthermore, these dependent claims are allowable *a fortiori* for substantially the same reasons presented above. Each of these dependent claims depends from

and therefore includes all of the limitations of one of Claims 1, 10, or 14, which distinguish patentably over the cited combination of references. The cited combination does not disclose or suggest all of the limitations of the independent claims, let alone the additional unique combinations of limitations recited by the dependent claims. Accordingly, Applicants respectfully request that the rejection of dependent Claims 2-9, 11-13, and 15-23 also be withdrawn.

**C. Section 103(a) – Hofmeister in view of Tanaka, Ozawa, and Fishkin**

Claims 7 and 8 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Hofmeister in view of Tanaka and Ozawa, and further in view of U.S. Patent No. 6,082,948 to Fishkin *et al.* Fishkin is cited merely for disclosing a chamber that houses multiple substrates and has a volume less than 18.3 liters. However, Fishkin does not cure the abovementioned deficiencies of Hofmeister, Tanaka, and Ozawa. Accordingly, Applicants respectfully request that this rejection be withdrawn.

Moreover, Fishkin's "buffer chamber" 14 appears to be a chamber through which substrates must pass while moving from a carrier chamber 58 to a transfer chamber 82, as opposed to a chamber in which substrates can be temporarily stored without interrupting normal operations of the processing tool.

**D. Section 103(a) – Hofmeister in view of Tanaka, Ozawa, and Edwards**

Claim 9 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Hofmeister in view of Tanaka and Ozawa, and further in view of U.S. Patent No. 5,944,857 to Edwards *et al.* Edwards is cited merely for disclosing a loadlock chamber having an internal volume less than or equal to about 9.156 liters. However, Edwards does not cure the abovementioned deficiencies of Hofmeister, Tanaka, and Ozawa. Nothing in Edwards suggests combining a low-capacity loadlock chamber with a purgeable buffer chamber. Accordingly, Applicants respectfully request that this rejection be withdrawn.

**E. No Disclaimers or Disavowals**

Although the present communication may include alterations to the claims, or characterizations of claim scope or referenced art, Applicants are not conceding in this application that previously pending claims are not patentable over the cited references. Rather, any alterations or characterizations are being made to facilitate expeditious prosecution of this application. Applicants reserve the right to pursue at a later date any previously pending or other broader or narrower claims that capture any subject matter supported by the present disclosure, including subject matter found to be specifically disclaimed herein or by any prior prosecution. Accordingly, reviewers of this or any parent, child or related prosecution history shall not reasonably infer that Applicants have made any disclaimers or disavowals of any subject matter supported by the present application.

**F. Conclusion**

In view of the foregoing amendments and remarks, Applicants respectfully submit that this application is in condition for allowance. If there is any further hindrance to allowance of the pending claims, the Examiner is invited to contact the undersigned.

Please charge any additional fees, including any fees for additional extension of time, or credit overpayment to Deposit Account No. 11-1410.

Respectfully submitted,

KNOBBE, MARTENS, OLSON & BEAR, LLP

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US006073366A

**United States Patent** [19]**Aswad**[11] **Patent Number:** **6,073,366**[45] **Date of Patent:** **Jun. 13, 2000**[54] **SUBSTRATE COOLING SYSTEM AND METHOD**[75] **Inventor:** Thomas W. Aswad, Phoenix, Ariz.[73] **Assignee:** ASM America, Inc., Phoenix, Ariz.[21] **Appl. No.:** 09/110,544[22] **Filed:** Jul. 6, 1998**Related U.S. Application Data**

[60] Provisional application No. 60/052,263, Jul. 11, 1997.

[51] **Int. Cl.** F26B 3/08[52] **U.S. Cl.** 34/367; 34/451; 34/461; 34/62[58] **Field of Search** 34/329, 366, 367, 34/428, 60, 62, 444, 448, 461, 463, 430, 451, 433; 118/715, 724, 725, 729; 414/737, 752, 744.6, 744.8, 935**References Cited****U.S. PATENT DOCUMENTS**

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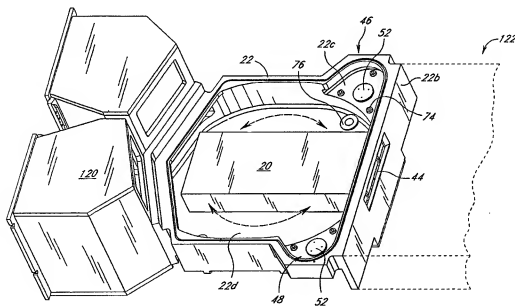
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**Primary Examiner**—Pamela A. Wilson  
**Attorney, Agent, or Firm**—Knobbe, Martens Olson & Bear, LLP

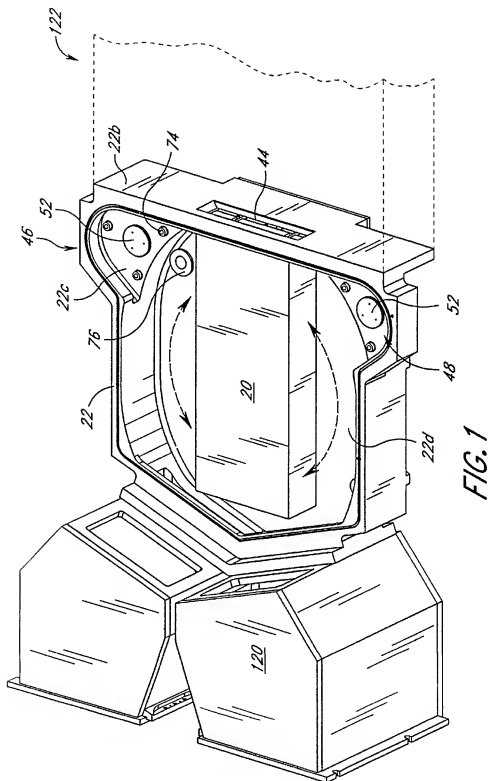
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**ABSTRACT**

A method and apparatus is disclosed for cooling a substrate between high temperature thermal processing steps. In the disclosed embodiment, one or more cooling stations are located off-line within a wafer handling chamber, just outside the thermal processing chamber. After thermal processing, a hot wafer can be loaded on to the cooling station, where the wafer is subjected to forced convection cooling. In particular, the wafer is subjected to cooling gas from above and below through perforated upper and lower shower head assemblies. The wafer can thus be cooled rapidly on a cooling station while other wafers are transferred into and out of the processing chamber. Desirably, the wafer is cooled on the cooling station to a point at which it can be handled by a low temperature wafer handler and stored in a low temperature cassette.

**14 Claims, 9 Drawing Sheets**





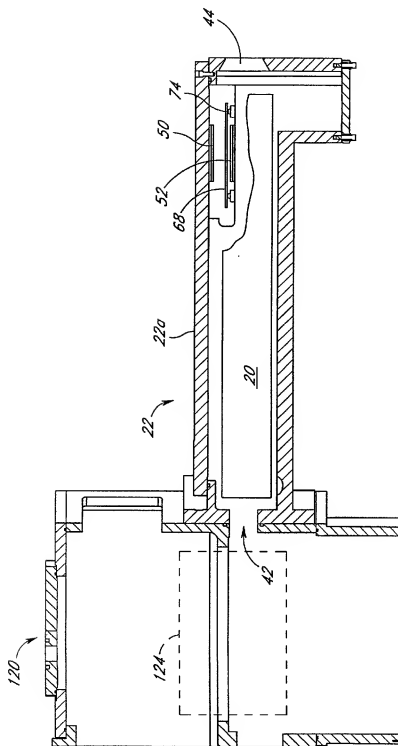
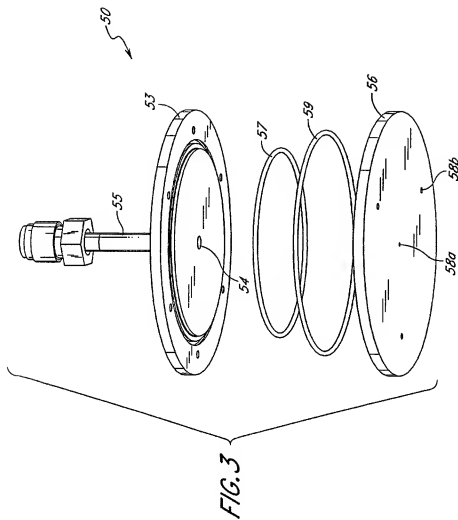
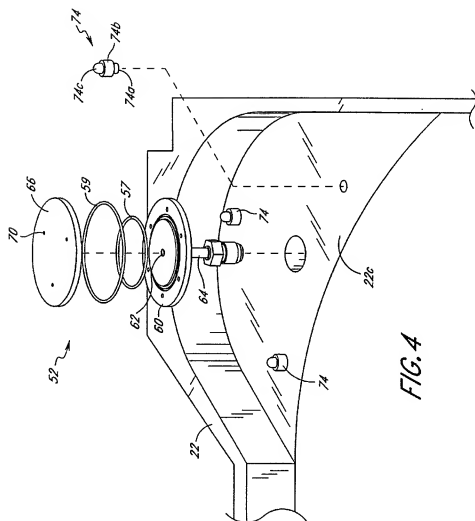


FIG. 2





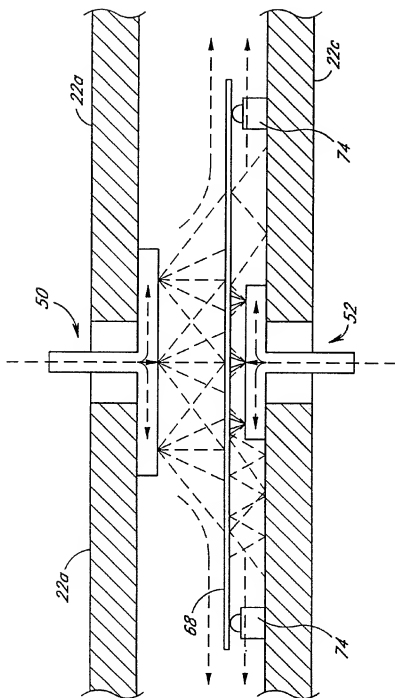
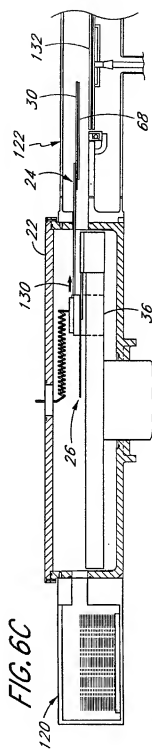
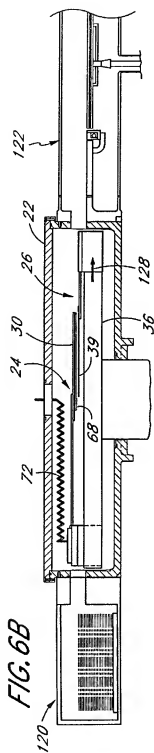
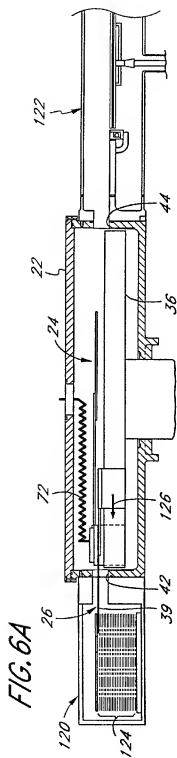


FIG. 5



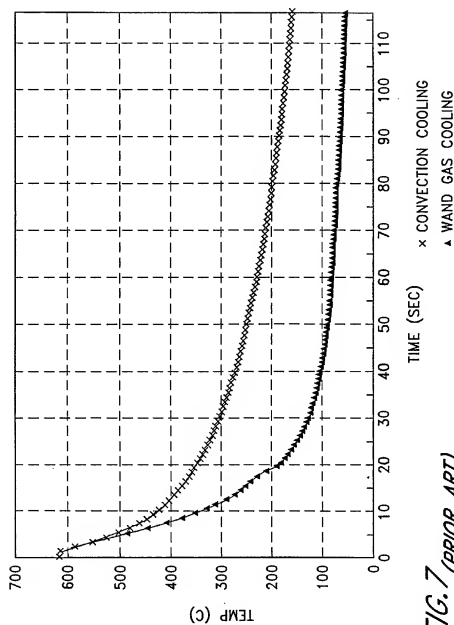


FIG. 7 (PRIOR ART)

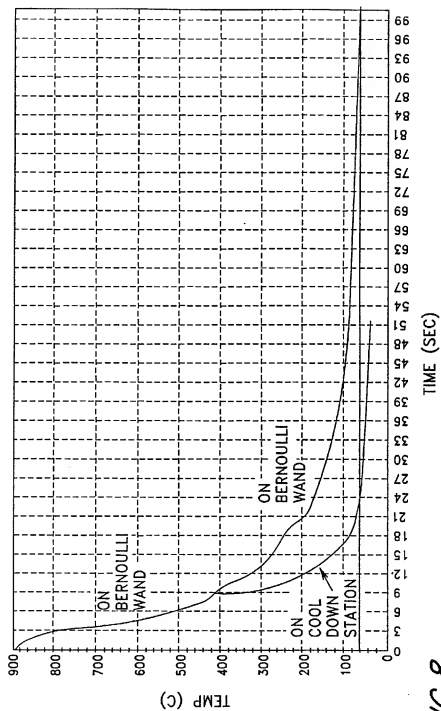
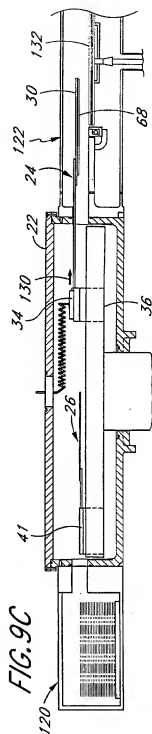
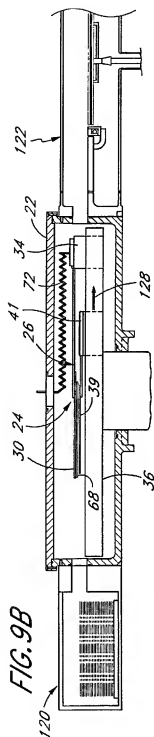
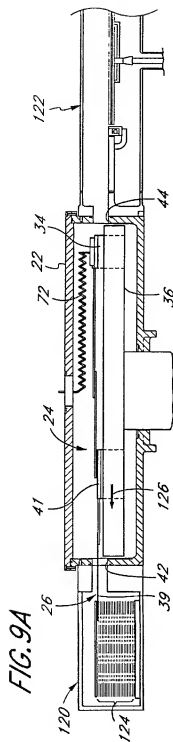


FIG. 8





# SUBSTRATE COOLING SYSTEM AND METHOD

## RELATED APPLICATIONS

Pursuant to 35 U.S.C. §119(e), this application claims the priority benefit of provisional application Ser. No. 60/052, 263, filed Jul. 11, 1997.

## FIELD OF THE INVENTION

This invention relates to an apparatus and a method for cooling a wafer-like substrate in a substrate treating system. More particularly, the invention relates to cooling of a substrate by convection in a location not in the direct path of the treating system.

## BACKGROUND OF THE INVENTION

Semiconductor wafers or other such substrates are subjected to very high processing temperatures. For example, in chemical vapor deposition (CVD), the temperatures approach 1200° C. In a typical cycle, a wafer is transferred from a room temperature cassette by a robotic wafer handler into a reactor chamber where it is subjected to the high temperature processing and is then transferred by the wafer handler from the high temperature chamber back to the same cassette or a separate cassette for processed wafers. Because of the high temperature CVD processing, transport from the process chamber directly to a wafer cassette is not possible due to the temperature of the wafer exceeding the material properties of most commonly used cassette materials. Because of this, the transfer of the wafer to a cassette must be postponed until the wafer temperature falls below the thermal properties of the cassette material. While cassettes are available that can handle wafers as hot as 170° C., they are relatively expensive. A commonly available less expensive one made of Delrin® can only handle temperatures well below 100° C. Other commonly available units can only handle about 60° C. Hence, it is a desirable goal that the temperature of a wafer be quickly cooled to that level.

Because the wafer handling and processing occurs in an enclosed and carefully controlled environment, there are essentially only three locations or points during the cycle where the cooling of the wafer might occur. The wafer could be cooled on the susceptor on which it is supported in the process chamber, on the wafer handling device, or off-line at some location within the apparatus. Cooling the wafer on the susceptor is not cost-effective because the process chamber is then unavailable for processing another wafer, thereby reducing the system wafer throughput. This approach is particularly unattractive because it is then necessary to incur the delay and cost of reheating the chamber. Removing a wafer while it is hot and cooling it on the wafer handling device is better, but also not cost effective because the delay in loading the next wafer slated for processing compromises throughput. Such impediments increase the per-wafer cost, making these approaches financially unattractive to end users. Because of the high cost of semiconductor wafer processing equipment, it is, of course, critically important from a competitive standpoint to be able to keep the expensive equipment in continued use so as to increase the throughput. At the same time, the wafer cooling technique employed must be compatible with the environment of the CVD processing apparatus so as not to adversely affect stringent cleanliness requirements. Also, the cost of the technique must itself be sufficiently moderate so that there is a net reduction in the per-wafer cost.

Accordingly, it is an object of this invention to provide an improved system for quickly cooling wafer-like substrates to

a temperature that will allow the use of low cost commonly available cassettes.

## SUMMARY OF THE INVENTION

In accordance with the invention, a substitute or cooling station is provided in a wafer handling chamber located between a wafer input/output storage area and a wafer process chamber. The cooling station is located so that the wafer handling device may be utilized while a wafer is cooling to transfer another wafer from storage into a process chamber and to transfer a cooled wafer into storage while the wafer is being processed.

In a preferred form of the apparatus and method, a processed wafer is withdrawn from the process chamber at a high temperature and placed by the wafer handler into a cooling station where it is sprayed by gas which is compatible with the gases being utilized in the wafer handling chamber. Preferably, the gas is sprayed onto both flat surfaces of the wafer by an upper showerhead and by a lower showerhead. While that wafer is being cooled, the wafer handler is operated to transport a second wafer into the process chamber.

It is desirable that a second cooling station be provided on the opposite side of the wafer handling chamber from the first one so that a second wafer may be moved from the wafer storage area into the second cooling station. Thus, as soon as the first wafer is transferred from the process chamber into the first cooling station, the wafer handler may move directly to the second cooling station and move that second wafer into the process chamber. In such an arrangement, the second cooling station is, in effect, serving as a staging area so that the time for moving the second wafer into the process chamber is reduced from what it would be if the wafer handler had to move the second wafer from the wafer storage area into the process chamber. Alternatively, if it is necessary to have a wafer cooling in each station at the same time, a wafer may be transported directly from the storage area to the process chamber.

In a preferred form of the invention, the wafer handler includes a Bernoulli wand which is particularly well adapted for moving a wafer into and out of a process chamber, and further includes a paddle, particularly well adapted for moving a wafer into and out of a common cassette for wafers. It is advantageous to be able to use the high temperature wand because it does not touch the upper surface of the wafer and it cools as it carries. Further, using the paddle for transporting a wafer between the cassette and the cooling station is desirable because it fits between wafers in a standard cassette.

Another advantage of the system of propelling gas against the surfaces of a wafer in a cooling station is that the rate of cooling may be easily controlled by the rate at which the cooling gas is projected onto the wafer. Thus, the flow rate can be adjusted to minimize the overall cycle time. The overall system provides a significant reduction in the wafer processing time and, consequently, reduces the cost per wafer. Further, this advantage is obtained without adverse effect on the clean environment required in CVD apparatus.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective, somewhat schematic view of a wafer handling station and adjacent portions of a CVD apparatus.

FIG. 2 is a cross-sectional view of the wafer handling chamber and wafer input or output chambers.

FIG. 3 is an exploded perspective view of an upper showerhead of the cooling station of the invention.

FIG. 4 is an exploded perspective view of a lower showerhead of the cooling station of the invention.

FIG. 5 is a schematic, cross-sectional view of the cooling station of the invention in operation.

FIGS. 6a, 6b and 6c are side cross-sectional, somewhat schematic views of one form of a wafer handler which can be used with the cooling stations of the invention.

FIG. 7 is a graph indicating the rate at which a wafer is cooled by unassisted prior art convection cooling and by cooling while being supported by a pick-up wand utilizing gas for that purpose.

FIG. 8 is a graph illustrating the time to cool a wafer on a prior art pick-up wand in comparison to cooling in a cooling station of the invention.

FIGS. 9a, 9b and 9c are side cross-sectional, somewhat schematic views of a variation of wafer handlers of FIG. 6.

#### DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2, there is illustrated a portion of a chemical vapor deposition apparatus, including a schematically illustrated automatic or robotic wafer handler 20 centrally positioned within a handling chamber 22. The chamber upper wall 22a is schematically shown in FIG. 2, but is not shown in FIG. 1 so as to illustrate internal components in the chamber. The handling chamber is connected to load/unload chambers 120 by way of a load/unload port 42. FIG. 1 illustrates a separate load chamber and a separate unload chamber. FIG. 2 shows a single one of those chambers. Many systems utilize a single chamber from which a wafer is withdrawn for processing and is then returned after processing. Either may be referred to as a storage area. The handling chamber 22 is further connected to a processing chamber 122, schematically illustrated in FIG. 1, by way of a processing port 44 through a sidewall 22b of the handling chamber. Gates or valves are normally provided for the load/unload port and the processing port, but these are not shown for purposes of simplicity.

In accordance with the invention, there is provided a wafer cooling station 46 in one portion of the wafer handling chamber 22 adjacent the process chamber 122. Further, a second cooling station 48 is located on the other side of the wafer handling chamber adjacent the wall leading to the process chamber. Each cooling station is sized to receive in a horizontal position one wafer, and the cooling station is open to the area of the handling chamber in which the wafer handler is positioned so that wafers may be moved into and out of the cooling stations by the handler.

Each cooling station includes an upper showerhead assembly 50 spaced above a lower showerhead assembly 52, as seen in FIGS. 1 and 2. Referring to FIG. 3, the upper showerhead assembly includes a disc-shaped base 53 having a centrally located gas inlet 54 which is connected to an inlet conduit 55, which, in turn, is connected to a suitable source of gas (not shown). A disc-shaped showerhead 56 is clamped to the base with suitable fasteners (not shown). An O-ring 57 fits between the base and the head to form a flat circular manifold space. A second O-ring 59 fits between these components around a belt ring. There is a plurality of gas outlet holes formed in the showerhead, one hole 58a in the center and three others 58b equally spaced radially and circumferentially with respect to the center.

Referring to FIG. 4, it may be seen that the lower showerhead assembly 52 has a construction similar to that

for the upper cooling station. This includes a lower showerhead base 60 having a centrally located gas inlet 62 connected to a conduit 64 which, in turn, is connected to the same gas source (not shown) as the upper showerhead assembly. A disc-shaped lower showerhead 66 is clamped to the lower showerhead base by suitable fasteners (not shown) with the O-rings clamped between the two components to seal a flat disc-shaped gas manifold formed between the lower base and showerhead. Three gas outlet holes 70 opening to the handling chamber are shown formed in the lower showerhead equally spaced radially and circumferentially from the gas inlet 62 in the lower base. The ring of holes is on a smaller diameter than that for the upper assembly 50 so that the holes 70 are radially offset from the holes 58b. Also, the holes 70 and 58b of the two assemblies are circumferentially offset so that these holes are spaced about 60°.

Additionally shown in FIG. 4, as well as in FIGS. 1 and 2, are three quartz pins 74 for supporting a wafer 68 positioned in the cooling station. Each pin includes a generally cylindrical base 74a that fits into a socket in a lower shelf 22c forming the cooling station floor with a larger cylindrical portion 74b engaging the shelf and with an upper tip 74c. The tip preferably has a hemispherical or hemiphallic shape so as to have minimum contact with the wafer. The shelf is spaced upwardly from the bottom wall 22d of the handling chamber so that wafer lifting elements of the handler 20 will be suitably aligned with the cooling station.

Also shown in FIG. 1 as part of the cooling station control system is a sensor 76 mounted in the floor 22d of the handling chamber. The sensor is located below the area that an edge of wafer 68 in the cooling station 46 extends over the sensor so that the sensor can sense the presence or absence of a wafer in the cooling station.

FIG. 5 schematically illustrates the cooling station wherein it can be seen that the upper showerhead assembly 50 is located adjacent the upper wall 22a of the handling chamber and the lower showerhead assembly 52 is supported on the shelf 22c. The wafer 68 is shown positioned between the two showerhead assemblies on the wafer supports 74. As can be seen, the showerhead assemblies are smaller in diameter than the wafer so as not to extend over the sensor 76 and so as not to interfere with rotation of the handler 20. As indicated by the arrows, cooling gas is jetted downwardly onto the upper surface of the wafer and upwardly onto the lower surface of the wafer.

Referring to FIGS. 6a, 6b and 6c, there is schematically illustrated one form of a wafer handler 20. Various systems are known for handling wafers within semiconductor processing systems. One type of pick-up device is that known as a Bernoulli wand which utilizes jets of gas downward from the wand toward the wafer that then flow radially outward to create a region of lower pressure between the wafer and the wand, thereby lifting it. The Bernoulli wand advantageously avoids contact with the wafer, except, perhaps, at one or more small edge locators. One type of Bernoulli wand is shown in U.S. Pat. No. 5,080,549 to Goodwin, et al, which is incorporated herein by reference.

Another type of wafer pick-up wand utilizes a vacuum force and, thus, must be in intimate contact with the wafer. U.S. Pat. No. 4,566,726 to Corenti, et al, discusses a combination of Bernoulli and vacuum pick-up devices.

A third type of wafer pick-up device is a simple paddle which lifts and supports wafers from underneath. Such a paddle is illustrated in U.S. Pat. No. 4,951,601 to Maydan, et al. That patent also illustrates a typical movement device

for translating wafers from location to location within processing systems. The wafer handler is capable of linear retraction and extension, as well as rotation about an axis.

U.S. Pat. No. 5,135,349 to Lorenz, et al., discloses a robotic handling system using two paddle-type pick-ups mounted on a common rotating base. Both pick-ups are adapted to extend linearly away from one another to speed handling of wafers within the processing system. The paddles are augmented with a vacuum generated through a plurality of holes in an end effector portion of each paddle; the vacuum being transmitted along a channel within the paddle.

While any of these various wafer handling systems can be modified or adapted for use with the cooling station concept of the present invention, FIGS. 6a, 6b and 6c, disclose a desirable handler which provides both a Bernoulli wand and a paddle. A complete description of such an arrangement is disclosed in U.S. patent application Ser. No. 08/784,711 filed Jan. 16, 1997, which is incorporated herein by reference. The figures illustrate a typical sequence of movement of pick-up arms 24 and 26 of the wafer handling assembly 20. As mentioned above, the handling chamber is attached to a load/unload chamber 120 on one end, and a processing chamber 122 on an opposite end. The ports 42 and 44 on opposite ends of the handling chamber are aligned with similarly sized ports in the load and unload processing chambers 120 and 122, respectively. A cartridge or cassette 124 is positioned within the load/unload chamber 120, and is adjustable in a vertical direction to align a particular wafer with the port 42. A controlling computer (not shown) provides instructions to motors and pulleys (not shown) to cause the pick-up arms 24 and 26 to translate along a guideway 36.

In a first motion, as seen in FIG. 6a, the pick-up arm 26 translates toward the chamber 120 in a left direction, as indicated by the arrow 126. A paddle 39 extends through the port 42 and beneath the cassette 124. As mentioned, the cassette may be vertically movable or the paddle 39 may be independently vertically movable to extend underneath the wafer without contact therewith, and then undergo relative vertical motion to lift the wafer from the cassette.

In FIG. 6b, the arrow 128 indicates the movement of the pick-up arm 26 into a position which places the wafer 68 directly beneath the wand 30. Gas flow to the wand is then initiated through the extension hose 72 to enable transfer of the wafer 68 from the paddle 39 to the wand 30.

After the wafer 68 has been lifted by the Bernoulli wand 30, the pick-up arm 24 translates toward the chamber 122 to the right, as indicated by the arrow 130 in FIG. 6c, to insert the wand 30 and wafer 68 into the processing chamber 122. In the arrangement shown, the processing chamber 122 is suitable for CVD and includes a rotatable susceptor 132 upon which the wafer 68 is placed. By stopping the flow of gas through the extension hose 72 and Bernoulli wand 30, the wafer 68 is dropped on the susceptor 132.

An advantage of the use of a paddle and a Bernoulli wand is that the paddle has a sufficiently thin profile to fit between wafers in a standard cassette to remove or insert wafers therein. The Bernoulli wand is somewhat thicker than the paddle, such that it normally requires specially designed cassettes, which adds to the expense of a system. However, the Bernoulli wand is particularly well-suited for transferring wafers into and out of a process chamber since it can easily withstand high temperatures and does not physically touch the wafer, except along one edge by one or more stops that help locate or position the wafer.

The above description of a wafer handler is only showing linear motion between a wafer storage area and a process chamber. However, with a suitable motor and drive system (not shown), the entire wafer handler can be rotated about a vertical axis in either direction to provide rotational as well as linear motion. The details of the linear drive system are disclosed in the above-referenced pending patent application. Also, the details regarding a rotational system, as well as additional details regarding the linear one, are available from Cybec Systems Inc. of Menlo Park, Calif. Other suitable drive arrangements are apparent to those with skill in this particular art and are described in the above-mentioned patents.

With a rotating wafer handler the pick-up arms 24 and 26 may be mounted to be moved in the same retracting and extending directions in the guideway 36. Such an alternative arrangement is shown in FIGS. 9a, 9b, and 9c. In FIG. 9a, the paddle pick-up arm 26 is shown having moved to the left to pick-up a wafer, as in FIG. 6a. The arm 24 however is shown in FIGS. 9a and 9b with its carrier 34 located on the right side of the handler. In FIG. 9b, the arm 26 has been retracted so that the paddle 39 and the wafer 68 are beneath the wand 30 so that the wafer can be transferred. The handler can then be rotated to be aligned with the process chamber. FIG. 9c shows the handler rotated with the carrier 34 having moved over the carrier 41, and the arm 24 extending the wafer into the process chamber.

The wafer handlers 20 described above are particularly useful with the cooling station of the invention because the Bernoulli wand can elevate and transport a wafer out of the process chamber while it is still hot. The wafer is, however, too hot to transfer directly to a load/unload chamber 120. Instead, the wafer handler is rotated a small distance so that the Bernoulli wand is aligned with one of the cooling stations. The Bernoulli wand is then extended to place the hot wafer onto the pins 74 in the cooling station 46.

While the first wafer is being cooled, a second wafer may be positioned into the process chamber. This second wafer may be retrieved from the cassette 124 by the paddle and transferred to the Bernoulli wand, or the second wafer may have been positioned into the second cooling station 48 while the first wafer was being processed. In that case, the handler only has to be rotated a short distance (about 100°) from the first cooling station 46 to align the wand with the second cooling station 48 to withdraw the second wafer, and then rotate back (about 50°) to the position where the second wafer can be inserted into the process chamber. The second cooling station 48 in that situation is serving as a staging area. After the second wafer has been placed into the process chamber, the first wafer can be removed from the first cooling station and returned to the storage area 120 assuming it has been adequately cooled by then. Immediately after placing a processed wafer into the storage area, a third wafer can be withdrawn from the cassette 124 and moved to one of the cooling/staging stations to await its turn to be placed in the process chamber. From the foregoing, it can be appreciated that great flexibility is provided in the handling of the wafers so that the wafers can be moved in various sequences to fit with the temperatures and times of the processes being used by the system and with the time required to cool the particular wafers to the temperature desired before returning the wafer to the standard cassette.

Refer now to FIGS. 7 and 8 to gain a better appreciation for the cooling obtained from initial experimental uses of the invention. FIG. 7 in the upper left of the graph indicates a prior art cooling curve for a wafer that is simply cooled by convection without forced gas flow over the wafer surface

other than slight purge gas flow through a chamber. As seen, a wafer which was at slightly more than 600° C. initially cools to a temperature of 400° C. in about 12 or 13 seconds. However, the temperature does not drop to 200° C. until about 80 seconds from the initial starting point. Further, even after close to 120 seconds the temperature is still about 160° C., at which temperature it is still necessary to use an expensive cassette.

The lower curve in FIG. 7 indicates the condition in which a Bernoulli wand is utilized to lift a hot wafer and move it into the handling chamber with the wafer being cooled by the gas flowing out of the Bernoulli wand. This is the conventional prior art situation for handling a wafer with a Bernoulli wand. As may be seen, the temperature drops quickly to about 300° C. after about 12 seconds, which is much faster than the wafer simply cooled by convection without appreciable gas flow. Further, the temperature has dropped to 200° C. after about 20 seconds, and dropped to 100° C. after 40 seconds. It then takes almost an additional 60 seconds to lower the temperature to about the desired, 60° C. at which temperature it may be received in a commonly available relatively low-cost cassette. While the wafer is being cooled on the Bernoulli wand, neither it nor the process chamber can, of course, be utilized for another wafer. Further, while the wafer could be transferred from the wand to the paddle to save some handling time, it would then no longer be receiving the cooling gas expelled by the Bernoulli wand so that greater time would be required.

By contrast to the foregoing, refer to FIG. 8 which illustrates the greatly improved situation obtained from the cooling stations of the invention. The graph shows a hot wafer being removed from the chamber at a temperature of close to 900° C. by the use of the Bernoulli wand. The temperature has dropped to about 400° C. by the time the Bernoulli wand has been retracted to the handling chamber, the wafer handler rotated to align the wand with a cooling station, and the wand extended to place the hot wafer in the cooling station. This takes approximately 9 seconds in the example illustrated and the temperature of the wafer has dropped by then from 900° C. to 400° C., which is consistent with the wand gas cooling of FIG. 7. The upper line continuing from that point, as shown on the graph of FIG. 8, shows the cooling if the wafer is simply left on the Bernoulli wand as described above in connection with FIG. 7. The lower curve in FIG. 8 shows the reduction in temperature of the wafer placed in the cooling station. As can be seen, the temperature of the wafer drops another 200° C. to about 100° C. after only 3 seconds in the cooling station. Further, the temperature is down to about 100° C. in another 5 or 6 seconds, only 17 or 18 seconds from the time the wafer is lifted by the Bernoulli wand in the process chamber. Further the wafer temperature has dropped to the 60° C. level after approximately 24 seconds from the beginning. This is in contrast to the temperature not dropping to that level remaining on the Bernoulli wand until after over 100 seconds from the beginning, and much longer if only on a paddle. Thus, it can be seen that there is a very dramatic reduction in the time required to adequately cool the wafer before it can be placed in the low-cost cassette.

In addition, as explained above, the wafer handler is available to place a second wafer into the chamber as soon as the first wafer has been placed into the cooling station, which in the example indicated by the graphs in FIG. 8, would be after about 9 seconds from the time the wafer has been lifted in the process chamber. If a second wafer has been placed into the second cooling station utilizing it as a staging area while the first wafer is being processed, the

wafer handler only has to rotate to be aligned with the second cooling station so as to allow the Bernoulli wand to lift and place a second wafer in the process chamber. When the first wafer has been adequately cooled, the wafer handler may be rotated so that the paddle is aligned with the cooling station to withdraw the cooled wafer. The wafer handler can then be rotated so that the paddle 26 is aligned with the cassette and the paddle is utilized to place the cooled wafer into the cassette.

The time to pick-up a hot wafer, take it to the cooling station, pick-up a second wafer from the staging station and place it in the process chamber, retract the wand, and close the process chamber gate is about 33 seconds. The time required under the old system for that sequence was about double that, not counting cooling time. That is the time savings simply by having the cooling stations for staging. Further, it would take about another 45 seconds under the old system to cool the wafer to be able to place it in a low cost cassette.

Further details regarding the structure and operation of the cooling stations will enable a better understanding and appreciation of the invention. In a prototype of the system, the central hole 58a of the upper showerhead has a diameter of about 0.016 inch, and the surrounding three holes each has a diameter of about 0.026 inch. The three holes 70 in the lower showerhead has a diameter of about 0.028 inch. These holes are designed to produce a flow rate of about 20 liters of nitrogen per minute at a pressure of 20 psi from each showerhead. That is, both the upper surface and lower surface of the wafer receives gas at the rate of about 20 liters per minute.

The outlet holes in the showerheads that are spaced outwardly from the center are about 120 degrees apart. Preferably, the outlets from one of the showerheads are staggered with respect to the other, so that as a total, there is a gas outlet about every 60 degrees. The upper holes are on a ring having a larger diameter than the lower ring. Hence, the holes are also radially offset. This arrangement provides a more even dispersion of the gas flow.

The cooling gas employed is conveniently the same gas utilized for the Bernoulli wand, typically nitrogen or hydrogen. Hence, it can come from the same source. Further, after cooling gas flows across the wafer, it simply flows into the handling chamber and is withdrawn from the handling chamber by the same system normally employed in a handling chamber connection utilizing a Bernoulli wand.

Advantageously, the cooling time can be simply controlled by the gas flow rate. The object, as indicated above, is to get the temperature of the wafer down to about 60° C. before the robot paddle is utilized to pick up the wafer and transfer it to the low-cost cassette in the storage area. The time required to cool an 8 inch wafer with a flow rate of 20 liters per minute from each of the showerheads was about 20 seconds in an experimental system. Doubling the flow rate to about 40 liters per minute out of both showerheads reduced the cooling time down to about 12 seconds. Flowing cooling gas only through the top showerhead cooled the wafer to the desired level in about 35 seconds.

The distance between the plane defined by the tops of the three support pins and the upper showerhead can be slightly greater than the distance between that plane and the lower head because the wand is slightly thicker than the paddle. Spacing and gas flow may, of course, be varied to fit the given situation. In a prototype, the distance between the showerheads was about 1.125 inch, with the spacing from the wafer to the lower showerhead being only about 0.2 inch.

Based on the foregoing, it will be appreciated that the substrate cooling system of the invention has great flexibility such that many of the substrate handling sequences can be varied to fit a particular process cycle, with the main concept being that the process chamber can be placed into use with a second substrate while a first one is being cooled. While a particular type of wafer handler has been described, a variety of wafer handlers may be employed. Likewise, while a particular cooling station has been described, various other cooling stations may be employed. Although gas is utilized to cool the wafer, possibly other cooling mechanisms may be employed. While the invention is useful with a single cooling station, two cooling stations provide additional flexibility, and it is possible that an additional cooling station could be provided if desired. While a single process chamber has been illustrated and discussed, a so-called cluster system could be employed wherein additional process chambers may be clustered around the wafer handler. With the arrangement shown at least two additional chambers could be provided. Other variations of the invention may also be contemplated and, hence, it is intended that the scope of the invention not be limited to that illustrated.

What is claimed is:

1. An apparatus for cooling a substrate after a high temperature processing comprising:

a substrate handling chamber having a port through which a substrate may be moved to and from a storage area into a handling chamber, and having a port through which the substrate may be moved from the handling chamber into or out of a high temperature processing chamber;

an automatic substrate handler in the handling chamber for transporting a substrate to and from the storage area into and out of the process chamber; and

a cooling station in which a processed substrate may be moved by said handler to be cooled before being returned to the storage area, said station being located in a section of the handling chamber out of the path of the handler movement to enable a second substrate to be withdrawn from the storage area by the handler and placed in the process chamber while the first substrate is being cooled in the cooling station.

2. The apparatus of claim 1, wherein said cooling station includes upper and lower gas showerheads spaced from each other, and including supports for supporting a substrate between the showerheads and spaced from the showerheads, each of said showerheads being adapted to be connected to a source of cooling gas to enable cooling gas to be projected through openings in said showerheads onto the upper and lower surface of a substrate to cool the substrate.

3. The apparatus of claim 1, including a second cooling station accessible by the handler but located out of the path of the handler movement to enable the wafer handler to move a substrate from the storage area to the process chamber while a substrate is in said second cooling station.

4. The apparatus of claim 3, wherein said cooling stations are located one on each side of the port leading to the process chamber.

5. The apparatus of claim 4, wherein the cooling stations are positioned about 100 degrees apart such that the wafer handler only needs to be rotated about 50 degrees from the process chamber port to alignment with one of the cooling stations.

6. The apparatus of claim 1, wherein said wafer handler includes a paddle for withdrawing a wafer from the storage

area or placing a wafer into the storage cassette and includes a Bernoulli wand for lifting a substrate from above said paddle and said wand being movable and arranged so that a substrate may be transferred from the paddle to the Bernoulli wand or from the Bernoulli wand to the paddle, said paddle being sized such that it can fit between substrates stored in commonly available cassettes; and said process chamber port and said cooling station being constructed such that substrates may be moved into and out of said process chamber and into and out of said cooling station by said Bernoulli wand.

7. An apparatus for cooling a wafer substrate comprising: first and second shower heads spaced from each other and oriented towards each other so that fluid sprayed from the heads is sprayed towards each other; and

a support for supporting said substrate between said shower heads, said support being configured to cause fluid from said shower heads to spray onto opposite flat sides of said substrate.

8. A method of cooling substrates that have been subjected to high temperature processing, comprising:

providing a substrate handler capable of transporting substrates into and out of a high temperature process chamber;

withdrawing a hot substrate from the process chamber with said substrate handler and transporting said hot substrate into a cooling station accessible by the handler; and

inserting a second substrate into the process chamber with said handler while the first mentioned substrate is cooling in the cooling station.

9. An apparatus for cooling a substrate after a high temperature processing comprising:

a substrate handling chamber having a port through which a substrate may be moved to and from a storage area into a handling chamber, and having a port through which the substrate may be moved from the handling chamber into or out of a high temperature processing chamber;

an automatic substrate handler for transporting a substrate to and from the storage area into and out of the process chamber; and

a cooling station in which a processed substrate may be moved by said handler to be cooled before being returned to the storage area, said station being located out of the path of the handler movement to enable a second substrate to be withdrawn from the storage area by the handler and placed in the process chamber while the first substrate is being cooled, said cooling station including upper and lower gas showerheads spaced from each other, and including a support for supporting a substrate between the shower heads and spaced from the showerheads, each of said shower heads being adapted to be connected to a source of cooling gas to enable cooling gas to be projected through openings in said shower heads onto the upper and lower surface of a substrate to cool the substrate.

10. An apparatus for cooling a substrate after a high temperature processing comprising:

a substrate handling chamber having a port through which a substrate may be moved to and from a storage area into a handling chamber, and having a port through which the substrate may be moved from the handling chamber into or out of a high temperature processing chamber;

## 11

an automatic substrate handler for transporting a substrate to and from the storage area into and out of the process chamber;

a cooling station in which a processed substrate may be moved by said handler to be cooled before being returned to the storage area, said station being located out of the path of the handler movement to enable a second substrate to be withdrawn from the storage area by the handler and placed in the process chamber while the first substrate is being cooled; and a second cooling station accessible by the handler but located out of the path of the handler movement to enable the wafer handler to move a substrate from the storage area to the process chamber while a substrate is in said second cooling station.

11. The apparatus of claim 10, wherein said cooling stations are located one on each side of the port leading to the process chamber.

12. The apparatus of claim 11, wherein the cooling stations are positioned about 100° apart such that the wafer handler only needs to be rotated about 50° from the process chamber port to alignment with one of the cooling stations.

## 12

13. A method of cooling a thin, hot substrate that has been subjected to high temperatures in a chamber, comprising the steps of:

removing the hot substrate from the chamber with a substrate handler;

moving the handler and the hot substrate to a position between upper and lower showerheads;

depositing the hot substrate on spaced supports configured to position the substrate between and spaced from the showerheads;

withdrawing the handler from between the showerheads leaving the substrate on the supports; and

spraying gaseous coolant from the showerheads onto generally flat upper and lower surfaces of the substrate.

14. The method of claim 13 wherein said removing, moving, and depositing steps are performed with a Bernoulli wand which is positioned above the hot substrate and lifts the substrate without contacting said upper and lower surfaces of the substrate.

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